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Science 8

Module 4

Mechanical Systems

Home Instructor's Guide and Assignment Booklet 4A

Learning Technologies Branch

Alberta LEARNING

Science 8
Module 4: Mechanical Systems
Home Instructor's Guide and Assignment Booklet 4A
Learning Technologies Branch
ISBN 0-7741-2374-5

The Learning Technologies Branch acknowledges with appreciation the Alberta Distance Learning Centre and Pembina Hills Regional Division No. 7 for their review of this Home Instructor's Guide and Assignment Booklet.

This document is intended for	
Students	✓
Teachers	✓
Administrators	
Home Instructors	✓
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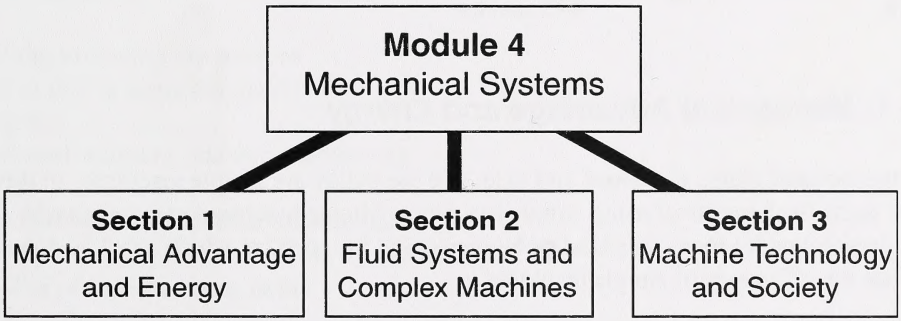
Module 4: Mechanical Systems

The major emphasis of this module is Science and Technology.

In this module the student will come to know that machines—large or small—perform jobs by controlling motion or by using energy to make things move. The student will discover how components of a machine are linked so that the machine works well. The student will compare old and new machines to see how they have improved over time. The student will also judge the quality of machines based on how efficiently they use energy, how well they do what they are supposed to do, and how they affect daily life, the community, and the environment.



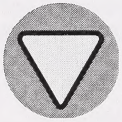
Assessment

The assessment of this module will be based on two Assignment Booklets. These will be weighted as follows:

Assignment Booklet 4A	
Section 1 Assignment	**49 marks**
Section 2 Assignment	**39 marks**
Assignment Booklet 4B	
Section 3 Assignment	**16 marks**
Final Module Assignment	**38 marks**
TOTAL	**142 marks**

Section 1: Mechanical Advantage and Energy

The lever, the inclined plane, the wheel and axle, and the pulley are simple machines. In this section the student will study the benefits of using simple machines. Simple machines can make tasks easier to perform by increasing the force on a load or by increasing the speed at which a task is done. The student also examines the efficiency of simple machines.



Safety goggles and latex gloves must be worn as a precaution while doing activities or investigations that involve the manipulation of materials and apparatus.

The following materials will be needed to complete this section.

Section 1: Lesson 1

- a protractor
- a strong stick or a board
- strong string
- a brick or a heavy mass
- a 10-N spring scale
- a toy car or other object for pulling up a ramp

- books or blocks for ramp support
- a smooth, flat board—preferably a little more than 1 m long (for example, a bookshelf or a propped-up table)
- a metric measuring tape or a metre-stick
- masking tape
- a pair of large scissors

Section 1: Lesson 2

- one of the following alternatives
  – a set of two or more toy gears
  – old gears
  – cardboard, scissors, and two thumbtacks
- two broom handles or similar smooth poles
- about 4 m of rope or strong twine

Section 1: Lesson 3

- two single pulleys
- 1-m mason's cord with a loop at each end
- a 10-N spring scale

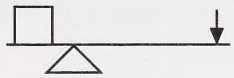
Suggested Answers

Section 1: Lesson 1

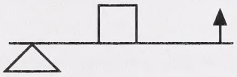
4. Textbook questions 1 to 4 from "Analyze" and "Conclude and Apply" on page 273:

1. **(a)** Two types of levers can exert a greater load force. They are the following:

- a Class 1 lever when the fulcrum is closer to the load than it is to the effort force



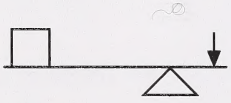
- a Class 2 lever—the fulcrum is always closer to the load than it is to the effort force



Note: In both cases the effort arm is longer than the load arm. The effort force moves farther than the load moves.

(b) Two types of levers can exert a load force less than the effort force. They are the following:

- a Class 1 lever when the fulcrum is closer to the effort force than it is to the load



- a Class 3 lever—the fulcrum is always closer to the effort force than it is to the load

Note: In both cases, students must use more effort force than if they just picked the object up to move it. The load arm is longer than the effort force arm. Therefore, the load moves farther than the effort force in the same amount of time. Although the load is harder to move, the load moves faster.

A simple machine that makes the load move faster than the effort force is said to give a speed advantage.

2. No, a Class 1 lever doesn't always exert a load force greater than effort force. When the load is farther from the fulcrum than the effort force, Class 1 levers provide a speed advantage. The effort force is greater than the weight of the object (F_L). When the fulcrum is in the centre, the Class 1 lever only changes the force's direction. The load force and effort force are equal.

3. The responding variable was the effort force (F_E).

   The manipulated variable was the arrangement of the fulcrum, load, and effort force.

   Note: The controlled variables were the lever length and the load force.

4. A Class 1 lever and a Class 2 lever can give a mechanical advantage (greater than 1) or a speed advantage, whereas a Class 3 lever always gives a speed advantage.

   Explanation: A Class 1 lever and a Class 2 lever can give a mechanical advantage greater than 1. Their mechanical advantage is greater than 1 when the load arm is shorter than the effort arm.

   A Class 3 lever always gives a speed advantage because the effort arm is always shorter than the load arm. Both a Class 1 lever and a Class 2 lever can give a speed advantage when the effort arm is shorter than the load arm.

5. **Questions about textbook Figures 4.5A, 4.5B, and 4.5C on page 274:**

Figure 4.5A illustrates a Class 2 lever. **Reason:** The load is between the muscle attachment and the toes. The muscle attachment is the position of the effort force, and the fulcrum is under the toes. Therefore, the load is in the middle.

Figure 4.5B illustrates a Class 3 lever. **Reason:** The effort is between the fulcrum and the load. This is shown in the diagram—effort is in the middle.

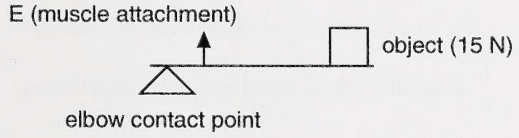
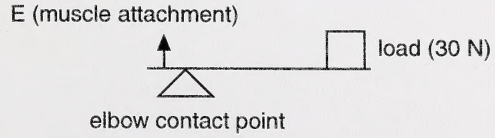


Figure 4.5C illustrates a Class 1 lever. **Reason:** The muscle attachment and the load are on opposite sides of the elbow contact point. Since the elbow contact is the fulcrum, the fulcrum is in the middle.



9. a. The greater the ramp length, the smaller the force needed.
b. The greater the slope angle, the greater the force needed.

10. a. The greater the ramp length, the greater the amount of work done.
b. The greater the slope angle, the smaller the amount of work done.

Note: For a wheeled object the friction may be insignificant. If friction is insignificant, the calculated work will be the same no matter the ramp length or slope angle.

11. a. Pulling a toy car up the ramp takes less force.
b. Lifting the toy car directly takes less work.

Note: If friction is small (as with a wheeled object), then the student will not notice a difference in the work.

17. Textbook questions 1 to 3 from "What Did You Find Out?" on page 280:

1. It is easier to cut the cardboard when the paper is close to the hinge. When used in this way, the Class 1 levers provide a force advantage.

2. Changing the location of the load changes the length of the load arm. Being closer to the hinge makes the load arm shorter. When the effort arm is longer than the load arm, the mechanical advantage is greater than 1. This provides a force advantage. Cutting is easier. When the load is at the tip, the load arm is longer so the mechanical advantage is less than 1. This provides a speed advantage.

3. In the photograph on the left, the effort arm is shorter than the load arm. In the photograph on the right, the effort arm is longer than the load arm.

Section 1: Lesson 2

7. Figure 4.15A

$$\text{Speed ratio} = \frac{\text{number of driver gear teeth}}{\text{number of driven gear teeth}}$$
$$= \frac{35}{25}$$
$$= 1.4$$

The speed ratio for Figure 4.15A is 1.4.

Figure 4.15B

$$\text{Speed ratio} = \frac{\text{number of driver gear teeth}}{\text{number of driven gear teeth}}$$
$$= \frac{35}{35}$$
$$= 1$$

The speed ratio for Figure 4.15B is 1.

8. Textbook questions 1 to 3 of "What Did You Find Out?" from page 288:

Answers will vary. **Note:** The gear train based on the "Gear Templates" (from the Appendix) may be discussed with the student. The mechanical advantage is the inverse of the speed ratio. Also, these ratios depend on which gear is the driver.

Using the large gear as the driver

$$\text{Speed ratio} = \frac{\text{number of teeth in driver gear}}{\text{number of teeth in driven gear}}$$
$$= \frac{20}{5}$$
$$= 4$$

The speed ratio of the gear train is 4. The mechanical advantage is the inverse of the speed ratio. The mechanical advantage is $\frac{1}{4}$.

Using the small gear as the driver

$$\text{Speed ratio} = \frac{\text{number of teeth in driver gear}}{\text{number of teeth in driven gear}}$$
$$= \frac{5}{20}$$
$$= \frac{1}{4} \text{ (or } 0.25\text{)}$$

The speed ratio of the gear train is $\frac{1}{4}$. The mechanical advantage is the inverse of the speed ratio. Therefore, the mechanical advantage is 4.

1. The smaller gear has a smaller radius and, therefore, a smaller circumference with fewer teeth.

2. The smaller gear would make three rotations for every one of the larger gears. The larger gear would be three times as big.

3. You can predict the number of turns a small gear will make for each turn of the large gear. You could use the radius, diameter, circumference, or number of teeth of each gear to make this prediction.

   The mechanical advantage of the gear train (described in question 2) depends on which gear is the driver and which is the driven gear.

   Suppose the larger gear is the driver. Then the speed ratio is 3.

   The mechanical advantage is the inverse of the speed ratio.

   $MA = \frac{1}{3}$ (or 0.33)

   The mechanical advantage is $\frac{1}{3}$.

   Suppose the smaller gear is the driver.

   Then the speed ratio is $\frac{1}{3}$ (or 0.33).

   The mechanical advantage is still the inverse of the speed ratio.

$$MA = \frac{1}{\frac{1}{3}}$$
$$= \frac{3}{1}$$
$$= 3$$

   The mechanical advantage is 3.

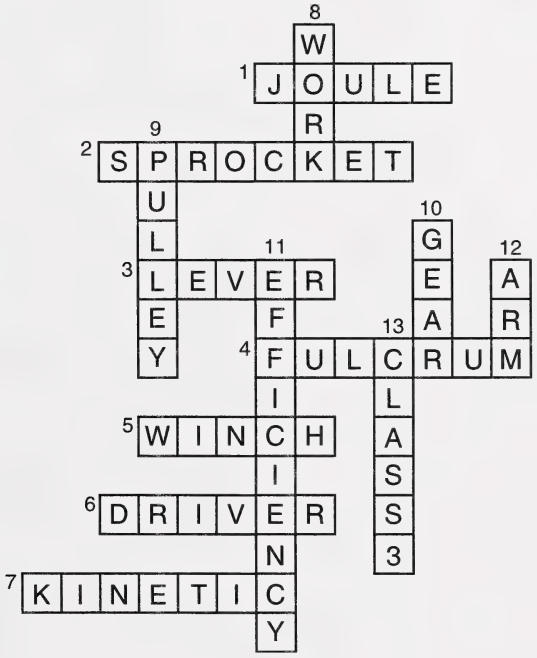
Section 1: Lesson 3

Answers to questions in Lesson 3 are in the Appendix of the Student Module Booklet.

Section Review

Textbook questions 1 to 13 (a crossword puzzle) and question 18 from "Wrap-up: Topics 1 to 3," page 303:

Answers to the crossword puzzle follow.



18. Machines do all of the things mentioned. Note the following:

- Simple machines can also act as linkages that transfer force or motion from one system component to another.
- Simple machines cannot do work on their own. They can only do as much work (on the load) as the work done in applying the effort force.

Section 2: Fluid Systems and Complex Machines

In this section the student examines two types of fluid systems—hydraulic systems and pneumatic systems. The student uses the relationship among force, pressure, and area to explain how fluid systems operate. Fluid systems can make tasks easier to perform by increasing the force exerted on a load. The student also sees how simple machines and fluid systems are combined to make complex machines.

The following materials will be needed to complete this section.

Section 2: Lesson 1

- three small balloons
- a blunt pencil
- a pin or a needle

Section 2: Lesson 2

- a small balloon

- one of the following alternatives
  – an empty thread spool, a 10-cm square piece of cardboard, and glue
  – a light funnel
  – the top curved part of a small pop bottle

- a pair of scissors

- paper

Section 2: Lesson 3

- construction materials for the "silly system" (See page 328 of the textbook.) (optional)

Suggested Answers

Section 2: Lesson 1

7. Textbook questions 1 and 2 from "Analyze," page 310:

1. Predictions will vary.

$$\frac{\text{area of large piston}}{\text{area of small piston}} = \frac{\text{mass on large piston}}{\text{mass on small piston}}$$

$$\frac{\text{area of large piston}}{0.5\,\text{m}^2} = \frac{1200\ \text{kg}}{40\ \text{kg}}$$

$$\text{area of large piston} = \frac{1200\ \text{kg}}{40\ \text{kg}} \times 0.5\ \text{m}^2$$

$$= 30 \times 0.5\ \text{m}^2$$

$$= 15\ \text{m}^2$$

The large piston has an area of 15 m^2.

2. This is not a practical design because it would require an enormous amount of hydraulic fluid and a lot of space.

8. a. $P = \frac{F}{A} = \frac{1200\ \text{N}}{3.0\ \text{m}^2} = 400\ \text{N/m}^2 = 400\ \text{Pa}$

The pressure is 400 Pa.

b. Rearrange the pressure formula.

$$F = P \times A = 400\ \text{N/m}^2 \times 10\ \text{m}^2 = 4000\ \text{N}$$

If a force of 400 N is being applied on every 1 m^2, the total force on 10 m^2 would be 4000 N.

c. $F = P \times A = 400\ \text{N/m}^2 \times 0.5\ \text{m}^2 = 200\ \text{N}$

If a force of 400 N is being applied on every 1 m^2, the total force on 0.5 m^2 would be 200 N.

9. Textbook questions 1, 2, and 4 from "Topic 4 Review," page 312:

1. Force is a push or pull. Pressure is the result of a force applied over an area.

2. Pascal is the name given to the combination of units N/m^2.

4. Pascal's law states the following:

> A confined fluid transmits an applied pressure undiminished and throughout the fluid in all directions.

Section 2: Lesson 3

3. Textbook questions 1 to 3 from "Analyze," page 328:

Designs will vary greatly. Can it be determined what is supposed to happen from the student's labelled diagram and written explanation? Can the student explain and show how the device transfers energy from one end of the system to the other? Did the student use scientific terms and concepts correctly? Would it, hypothetically, work? For example, the system shown in the textbook allows the inventor to shut off the alarm without getting out of bed. It is designed using the scientific concepts of energy transfer and conversion. Many of the steps will not work well for a variety of reasons. Problems with the design should lead to an interesting practical and scientific discussion.

4. Answers will vary. The energy transfer sequence for the design in the textbook, for example, would be as follows:

> cat → lever 1 → string (linkage) → lever 2 → book → string → wheel and axle → string → lever 3 → shoe → ball → button

5. Textbook questions 1 and 2 from "Topic 6 Review," page 330:

1. The student should examine a pencil sharpener if one is available. The subsystems of the pencil sharpener include the following:

- crank arm and handle—wheel of a wheel-and-axle system
- gears (perhaps)—connect the handle and cutters
- cutters—axle of a wheel-and-axle system (with wedges for cutting)
- rotating pencil guide—wheel-and-axle system
- shaving container and attachment
- mounting bracket and screws (The screws are simple machines.)

2. A force applied to the brake pedal lever pushes a piston that exerts pressure on the brake fluid. The pressure is transmitted equally throughout the hydraulic system, applying pressure to the wheel cylinder pistons. The wheel pistons move, exerting a force on the brake pads, which squeeze the disc. The resulting friction slows the car.

   A labelled diagram may have been included. This was not required.

Section Review

Textbook questions 1 to 4, 7, 9, and 10 from "Wrap-up: Topics 4 to 6," page 331:

1. **a.** pressure
   b. Pascal's law
   c. hydraulic system, closed system, or subsystem
   d. pascal
   e. hydraulic lift
   f. subsystem, closed system, or hydraulic system

2. The human heart generates the pressure to move fluid through the entire body.

3. The body's pneumatic system controls respiration—the taking in of oxygen rich air and getting rid of carbon dioxide.

4. Answers will vary. Pascal's law states that in a confined system, fluid pressure is equal in all directions.

7. The following are some differences between hydraulic and pneumatic systems.

Comparing Systems	
Hydraulic System	**Pneumatic System**
uses confined liquids	**uses confined gases**
liquids retained and reused	**gas often expelled into atmosphere during use**
incompressible liquids transfer force immediately	**uncompressed gas makes effective shock absorber**
	gas compressed to transfer force quickly and completely

9. A hovercraft rides on a low-friction cushion of air. Air is pumped under the craft and confined between the surface and the "skirt." When the air pressure is high enough, the craft rises off the surface of the ground or water. Forward propulsion is produced by propellers.

10. Fluid pressure plays a role in the careers of many rescue workers, firefighters, farmers, heavy-equipment operators, mechanical engineers, and healthcare workers.

ASSIGNMENT BOOKLET 4A

Science 8
Module 4: Section 1 Assignment and Section 2 Assignment

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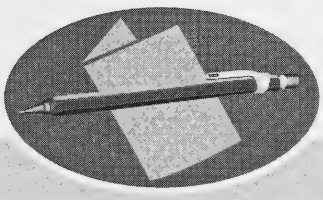
Science 8

Module 4

Mechanical Systems

Assignment Booklet 4A



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Summary

	Total Possible Marks	Your Mark
Section 1 Assignment	49	
Section 2 Assignment	39	
	88	

Teacher's Comments

Science 8
Module 4: Mechanical Systems
Assignment Booklet 4A
Section 1 Assignment and Section 2 Assignment
Learning Technologies Branch

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Students	✓
Teachers	✓
Administrators	
Home Instructors	
General Public	
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ASSIGNMENT BOOKLET 4A
SCIENCE 8: MODULE 4
SECTION 1 ASSIGNMENT AND SECTION 2 ASSIGNMENT

Your mark for this module will be determined in part by how well you do your assignments.

This Assignment Booklet is worth 88 marks out of the total 142 marks for the assignments in Module 4. The value of each assignment and each question is stated in the left margin.

Work slowly and carefully. If you have difficulty, go back and review the appropriate section.

Be sure to proofread your answers carefully.

Section 1 Assignment: Mechanical Advantage and Energy

49

Read all parts of your assignment carefully and record your answers in the appropriate places.

1. A student found that it took a force of 15 N to lift an object directly to a height of 1.5 m without the use of a machine. Then the student pulled the object up a ramp. The ramp height was also 1.5 m, but the length of the ramp was 4.5 m. It took a force of 5.2 N to pull the object up the ramp.

(2) **a.** What was the input work in using the ramp?

(2) **b.** What was the output work of the ramp?

(2) **c.** Explain why there is a difference between the input work and the output work.

(1) **d.** In what way does the ramp make the work easier?

(1) **2.** Circle the letter of the correct response.

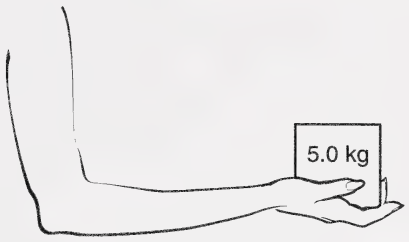
The mechanical advantage is defined as the ratio of load force to effort force. But you can find the mechanical advantage of a lever without even applying an effort. Just apply the following formula, which is based on characteristics of the lever itself.

$$MA = \frac{\text{effort arm length}}{\text{load arm length}}$$

For this formula to give the proper value of the mechanical advantage, which of the following must be true?

A. Work input is greater than work output.
B. Work input equals work output.
C. The effort arm length is greater than the load arm length.
D. A force of friction acts as the fulcrum.

Use the following diagram to answer questions 3 to 5.



The load force is 50 N.

Looking at the forearm as a lever, the load arm is 35.0 cm long. The effort arm is 5.0 cm long.

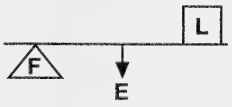
(1)

3. Circle the letter of the best response.

Which lever diagram best represents the forearm holding a weight?

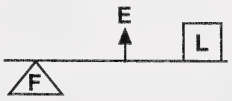
A.

B.



C.

D.



(3)

4. a. Determine the mechanical advantage of the forearm. Show your work with appropriate units.

(3)

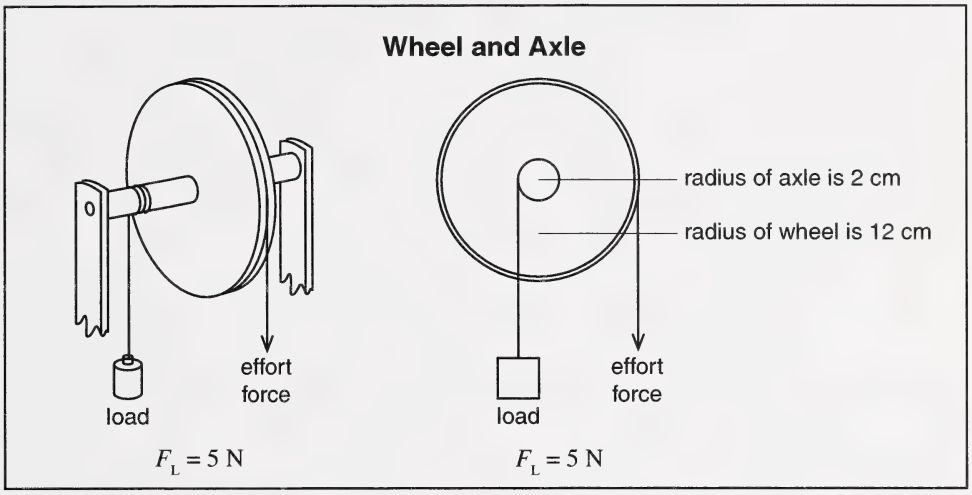
b. Determine the force the muscle must apply on the effort arm to have the forearm hold the object. Show your work with appropriate units.

(3)

5. How much work will be done on the object if the forearm lifts the object 0.25 m? Show your work with appropriate units.

Return to page 26 of the Student Module Booklet and continue with Lesson 2.

Use the following diagram to answer questions 6 to 9.



(3) **6.** Determine the mechanical advantage of the wheel and axle in the diagram. Show your work with appropriate units.

(2) **7.** What benefit does the wheel and axle provide—a force advantage or a speed advantage? Explain your answer.

_____

_____

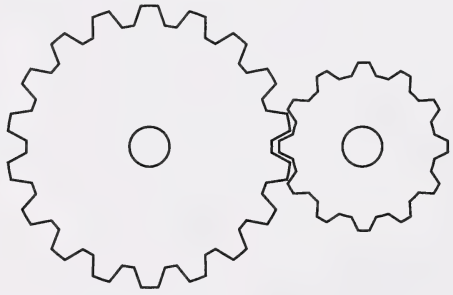
(2) **8.** Assume the force of friction is too small to make a difference in the way the wheel and axle turns. Determine the amount of work needed to lift the load up by 2.0 m using the wheel and axle. Show how you got your answer.

(1) **9.** How would you change the wheel and axle so that you would need even less effort force to lift the load?

_____

_____

10. Use the following diagram to answer questions 10.a. to 10.c.



(1) **a.** Which of the two gears rotates faster, A or B? Explain.

_____

_____

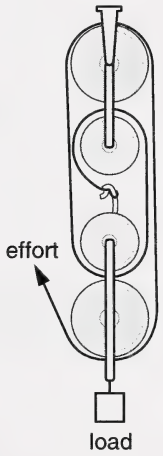
(3) **b.** Determine the speed ratio of this system. Show all your work, including the formula and the units.

(2) **c.** What two changes could you make to this system to have Wheel B rotate in the same direction as Wheel A?

_____

_____

11. Use the diagram to answer questions 11.a. and b.



(2) **a.** Determine the mechanical advantage of the pulley system in the diagram. Explain your answer. Ignore friction and the weight of the movable pulleys.

_____

_____

(2) **b.** Suppose you have to use an effort force of 10 N to lift the load with the pulley system. What is the weight of the load? Show your work with appropriate units.

Return to page 36 of the Student Module Booklet and continue with Lesson 3.

12. Using an old pulley system, a construction worker raises a 2000-N load 2.0 m by applying a 450-N effort force over a total distance of 10.0 m.

(3) **a.** Determine the efficiency of the block-and-tackle system. Show all your work, including the formula and the units.

(3) **b.** What is the actual mechanical advantage of the system? Show all your work, including the formula and the units.

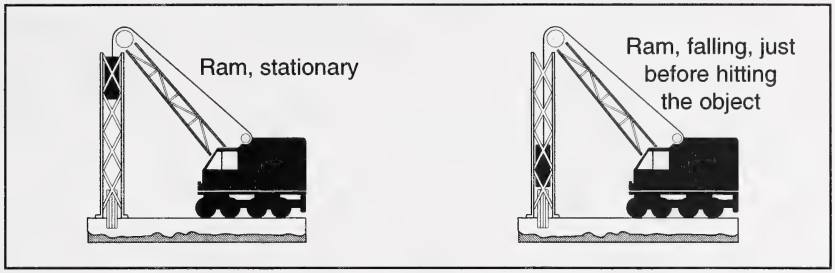
(1) **c.** Why would the mechanical advantage you calculated be different from the theoretical mechanical advantage?

_____

_____

13. Refer to the following diagram to answer questions 13.a. to 13.c. The graphic on the left is Diagram A, and the graphic on the right is Diagram B.

Consider the machine to be an "ideal" machine. That is, there are no energy losses due to friction.



(2) **a.** Identify the type of energy the ram possesses in each diagram.

A: _____ energy B: _____ energy

(2) **b.** Is the energy being transmitted or converted as the ram drops? Explain.

_____

_____

(2) **c.** Compare the amount of energy in Diagram A to the amount of energy in Diagram B. Explain your reasoning.

_____

_____

Return to page 42 of the Student Module Booklet and continue with Section 2.

39

Section 2 Assignment: Fluid Systems and Complex Machines

Read all parts of your assignment carefully and record your answers in the appropriate places.

(1)

1. a. Circle the letter of the best response.

You apply a force to a fluid in a closed container. The pressure in the container

A. is impossible to predict without more information
B. will remain the same
C. will increase
D. will decrease

(2)

b. Sketch and label a model hydraulic system with a mechanical advantage greater than 1. Include labels for the effort and load forces, arrows indicating direction of motion, and appropriate sizes of cylinders.

(2)

2. The area of the small piston of a hydraulic system is 0.1 m^2. Suppose a 50-N force is applied to the small piston. Determine the pressure applied on the hydraulic fluid. Show your work, including the formula and the units.

3. Suppose the smaller plunger of a hydraulic lift has an area of 2 cm^2. The area of the larger plunger is 8 cm^2. An effort force of 10 N is applied to the smaller syringe. This causes a load to be lifted on the larger syringe. Assume the force of friction is too small to make a difference.

(2) **a.** What is the fluid pressure while the effort force is causing the load to lift? Show your calculation.

(2) **b.** What is the force supporting the load at the larger plunger? Show your calculation.

(2) **c.** What is the mechanical advantage of the hydraulic lift? Show your calculation.

(2) **d.** Write a formula to show how the mechanical advantage relates to the areas of the plungers. Explain your work.

(2) **4.** Air is forced under a hovercraft to form an air cushion. What is the purpose of this air cushion?

_____

_____

Return to page 50 of the Student Module Booklet and continue with Lesson 2.

(2)

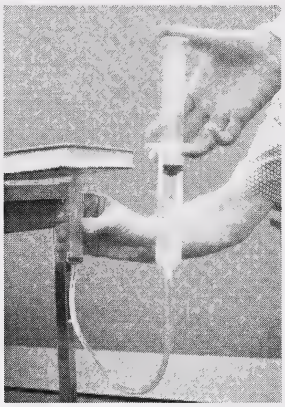
5. Refer to Figure 4.38 on page 316 of the textbook. The jackhammer, the hose carrying the air into the jackhammer, and its air supply form a system. Explain why this system is not considered a closed system.

_____

_____

_____

6. Use the following photograph to answer questions 6.a. and b.



Doran made a model to show how a force can be applied at a distance. Doran connected two identical, modified syringes with a hose. Doran put a load on the syringe placed farther away. Doran allowed the plunger under the load to drop to its lowest position in the syringe. Doran then applied a force on the nearer syringe.

The syringe system was airtight. Yet, when Doran applied a force with a thumb to the nearer syringe, the load, at the farther syringe, moved less than his thumb did.

(2)

a. Explain why the load moved a shorter distance than Doran's thumb.

_____

_____

_____

(2)

b. Describe what change Doran could make to the syringe system so there would be no loss in distance moved between the plungers of the syringes. Explain.

_____

_____

Return to page 54 of the Student Module Booklet and continue with Lesson 3.

7. Refer to Figure 4.52B on page 326 of the textbook. Analyze the brake-pedal system for questions 7.a. to 7.c.

When the driver applies the brake, a force is applied to brake pads on opposite sides of the disc.

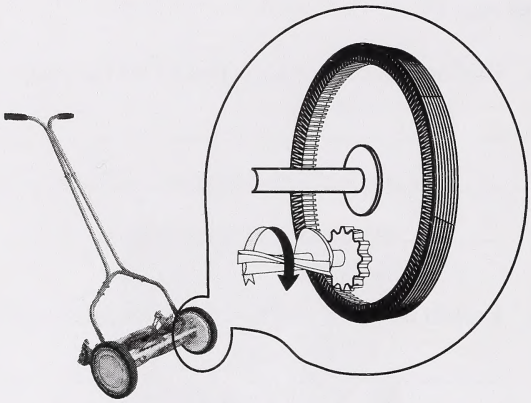
(2) **a.** Explain why the forces applied by the two brake pads are equal in size.

(1) **b.** Explain why you think the forces on opposite sides of the disc should be the same.

(2) **c.** Suppose you want to modify the hydraulic system so the brake pedal will be easier to push. What change will you make to the design? Explain why this change will help.

(2) **8.** Explain two design features of thumbtacks that make them easy to push into a bulletin board.

(4) **9. a.** Analyze the push mower. Use different colours to identify two different subsystems on the diagram. Create a name for each subsystem by using its specific function as part of the name.



(3) **b.** Label three different simple machine components (on the mower diagram) as specifically as possible.

(1) **c.** Why is it important that subsystems work properly?

_____

_____

(1) **d.** What is the source of energy for this push mower?

_____

10. During the mating season, male mountain sheep violently bash heads with other males to determine superiority. Their skulls completely cover a pneumatic system. This system is composed of many large and small sinuses (air pockets).

(1) **a.** What is the function of this system?

_____

(1) **b.** What do football players use for the same function?

_____

Submit your completed Assignment Booklet 4A to your teacher for assessment.
Then return to page 59 of the Student Module Booklet and begin Section 3.

ASSIGNMENT BOOKLET DECLARATIONS

The Student's Declaration is to be signed by a student registered at the Alberta Distance Learning Centre. If the student is under 16, the Supervisor's Declaration is to be signed by the student's supervisor, who is usually a home instructor, teacher, or home-schooling coordinator. Failure to complete this page may invalidate the assignment results.

STUDENT'S DECLARATION

- I have followed the instructions outlined in the Student Module Booklet.
- I have completed the activities to prepare myself for the assignments in this Assignment Booklet.
- I completed the assignments in this Assignment Booklet by myself.

_____

Student's Signature

SUPERVISOR'S DECLARATION

I hereby certify that I have supervised the learning activities completed by _____.

Student's Name

I also certify that to the best of my knowledge the assignments in this Assignment Booklet were completed independently by this student.

_____

Supervisor's Signature

If you, the student or supervisor, have any comments or observations regarding this module, write them in the following space.

_____

_____

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